



# Impact of Resist Parameters on Stochastic EUV Printability Failures

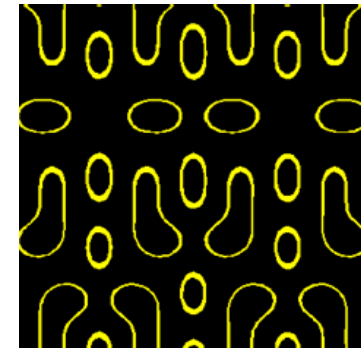
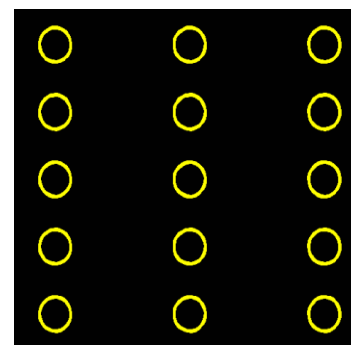
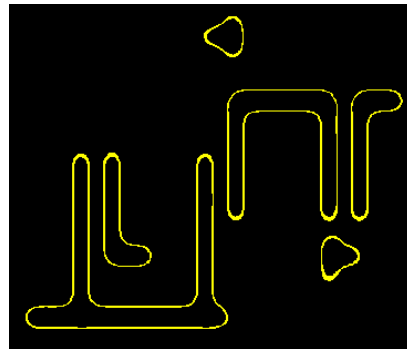
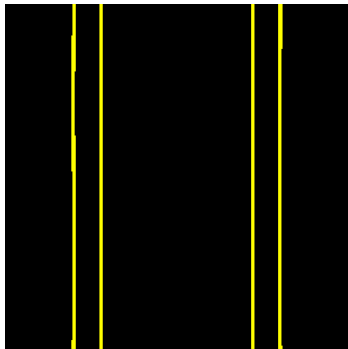
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# Stochastic Printability Failures

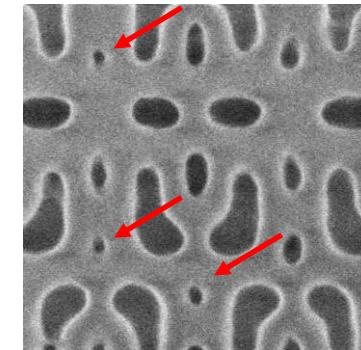
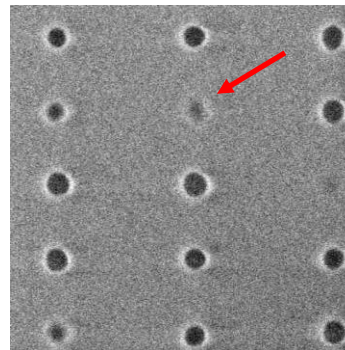
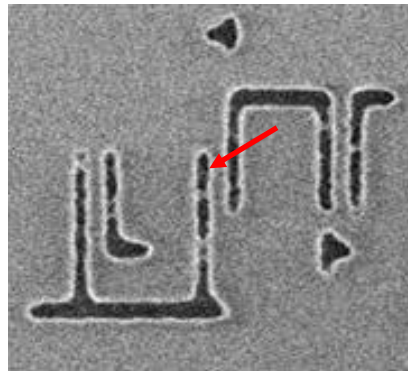
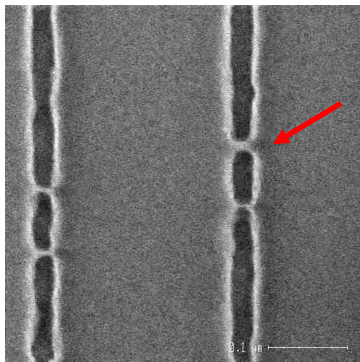
Examples from a Logic 10 nm node Local-Interconnect layer

OPC calibration says OK, but ...



Simulated  
PV band

Printing Failures happen



Patterned  
Wafer

**We attribute those issues to the stochastic effects in EUV.**

# Where do these stochastic effects come from?

Mask  
after OPC

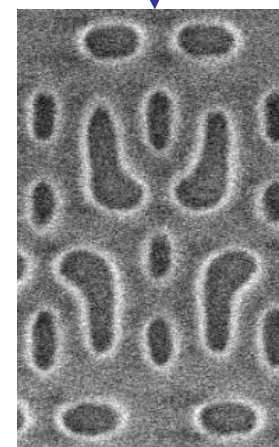
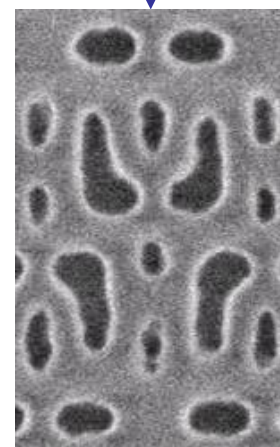
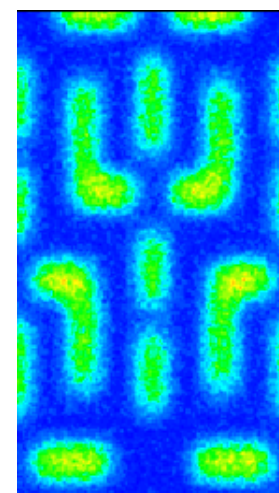
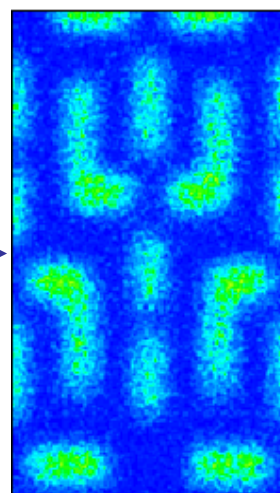
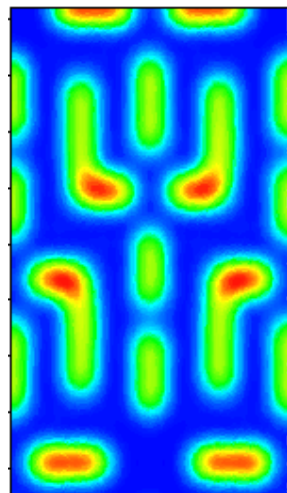
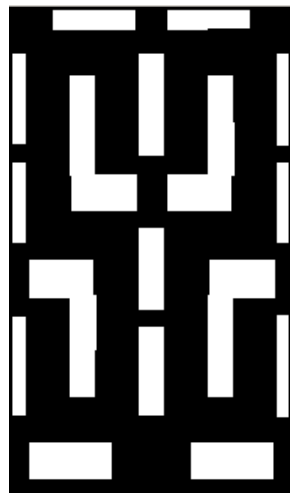
Image intensity  
= photon-absorption

Actual absorbed photons/nm<sup>3</sup>

Dose

Low dose

High dose



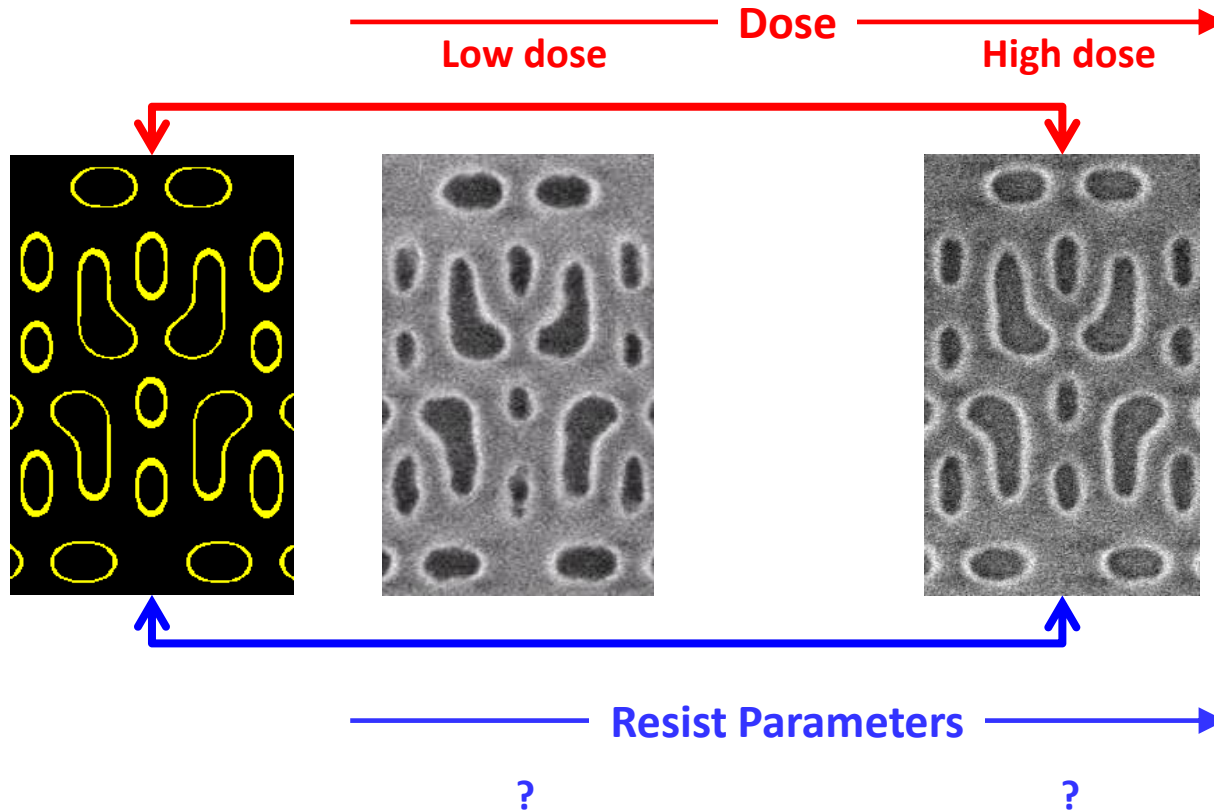
Our previous study revealed those failures decrease at higher dose.

→ Photon Shot Noise does impact.

But: this is not the only cause

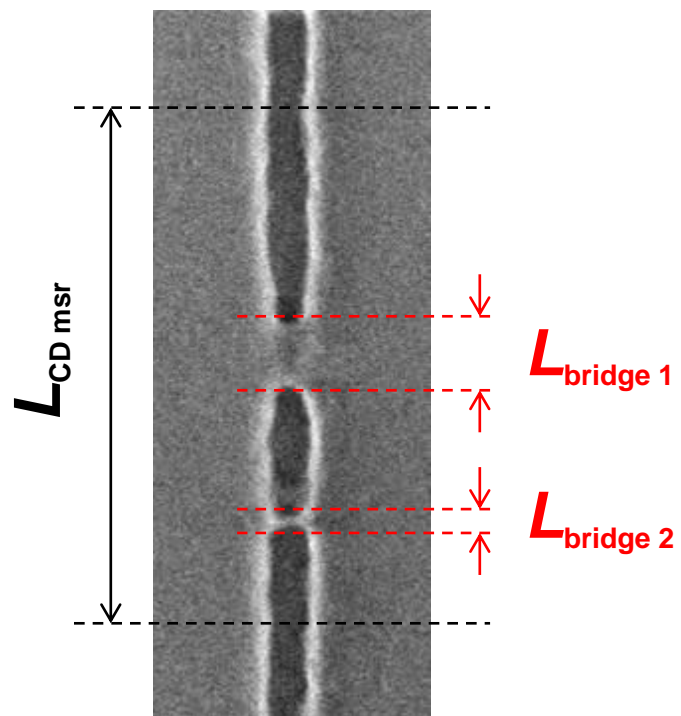
# Goal of this Study:

Investigate also impact of Resist Parameters



**High dose requires throughput reduction → Not preferable.  
Therefore we explored other path in resist parameters.**

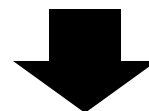
# Quantification of Printability Failures



The amount of local bridging in trench arrays is used to assess the probability of the printability failures.

It can be quantified from ;

1. Length along which the CD is measured  $\cdots L_{CD \text{ msr}}$
2. Total length of bridges in this area  $\cdots L_{\text{bridge}}$

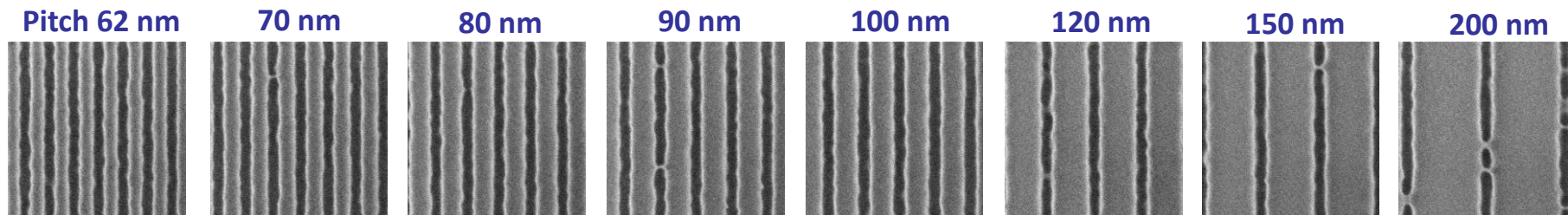


$$\frac{\sum \{L_{\text{bridge 1}} + L_{\text{bridge 2}} + \cdots\}}{L_{CD \text{ msr}}} = \text{NOK (\%)}$$

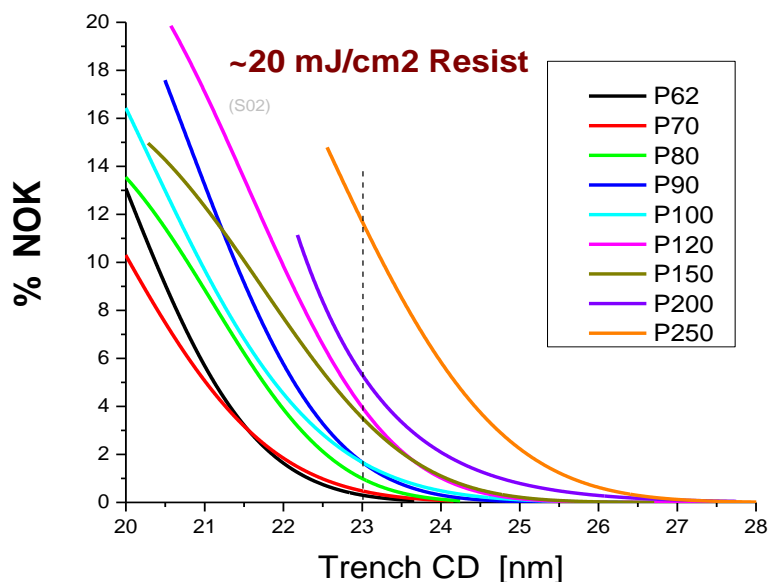
Taking statistics over multiple images

# Evaluation Feature

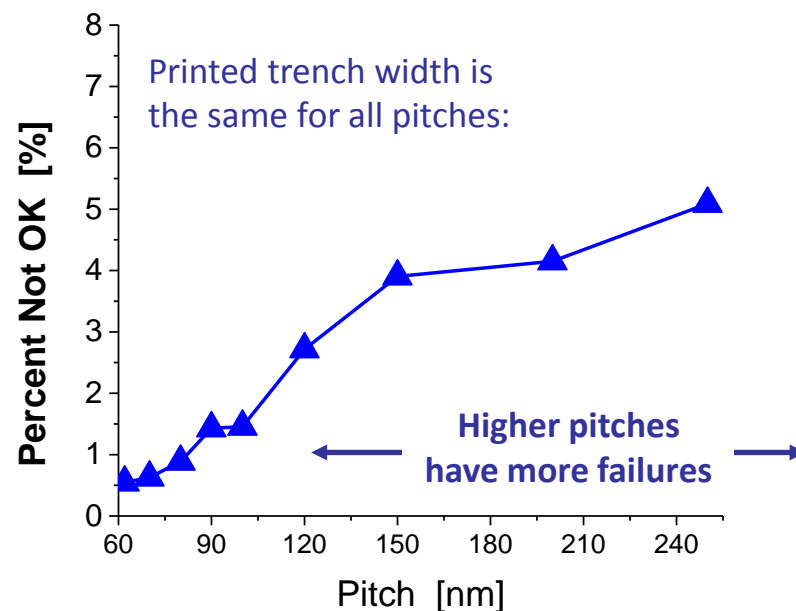
Peter De Bisschop et. al., SPIE 2014, 9048-8



**NOK(%) thru pitch**



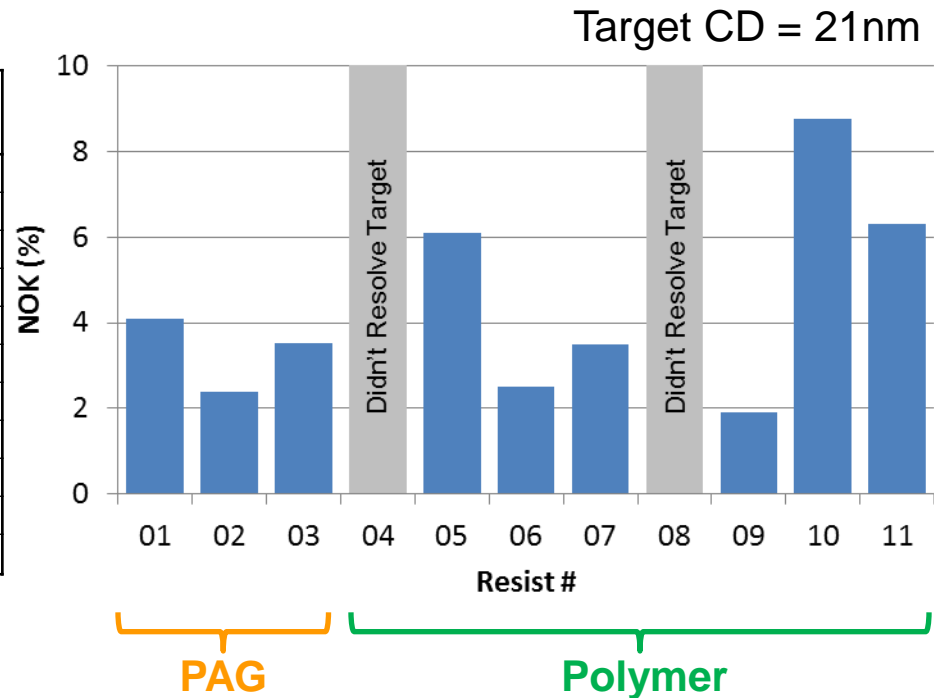
**NOK(%) @ CD target**



**We decided to qualify resists at 21nm CD through pitch 120-250nm**

# Resists & Results

Resist #	Polymer	PAG	Quencher	DtS (mJcm <sup>2</sup> )
Resist 01	Polymer-A	PAG-A	Q-A	33.5
Resist 02	Polymer-A	PAG-B	Q-A	34.2
Resist 03	Polymer-A	PAG-C	Q-A	33.3
Resist 04	Polymer-B	PAG-B	Q-A	34.6
Resist 05	Polymer-C	PAG-B	Q-A	34.6
Resist 06	Polymer-D	PAG-B	Q-A	36.4
Resist 07	Polymer-E	PAG-B	Q-A	35.1
Resist 08	Polymer-F	PAG-B	Q-A	35.1
Resist 09	Polymer-G	PAG-B	Q-A	36.9
Resist 10	Polymer-H	PAG-B	Q-A	30.6
Resist 11	Polymer-I	PAG-B	Q-A	31.9



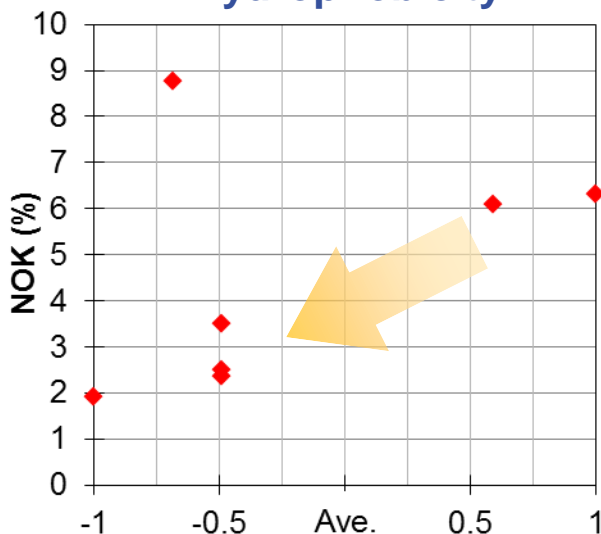
- 11 different resists with a similar DtS were evaluated to look into the impact of PAGs and polymers.
- Polymer does clearly have an impact on NOK.

# Polymer Parameters vs. NOK

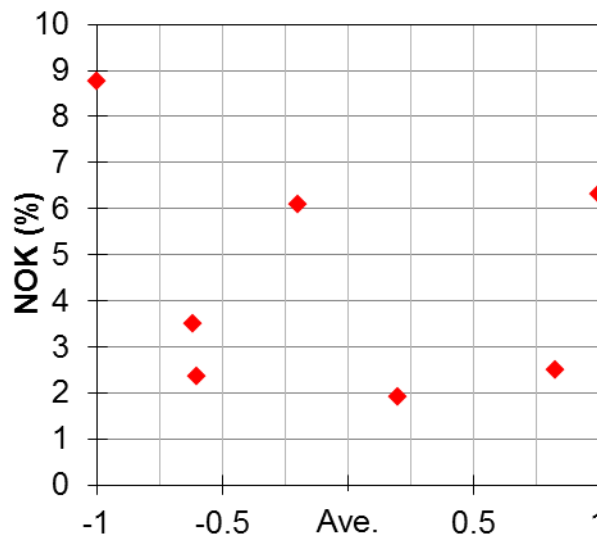
\*Normalized range around the average

Resist #	Polymer				PAG	Quencher
	name	Hydrophobicity*	Rmin*	Rmax*		
Resist 02	Polymer-A	-0.488	-0.600	0.077	PAG-B	Q-A
Resist 05	Polymer-C	0.594	-0.200	-0.538	PAG-B	Q-A
Resist 06	Polymer-D	-0.488	0.829	0.385	PAG-B	Q-A
Resist 07	Polymer-E	-0.488	-0.620	-0.231	PAG-B	Q-A
Resist 09	Polymer-G	-1 (lowest)	0.200	1 (highest)	PAG-B	Q-A
Resist 10	Polymer-H	-0.685	-1 (lowest)	-1 (lowest)	PAG-B	Q-A
Resist 11	Polymer-I	1 (highest)	1 (highest)	-1 (lowest)	PAG-B	Q-A

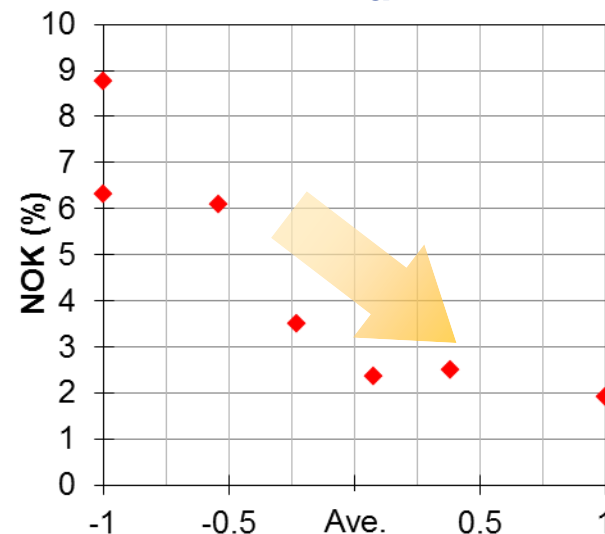
## Hydrophobicity



## Rmin



## Rmax

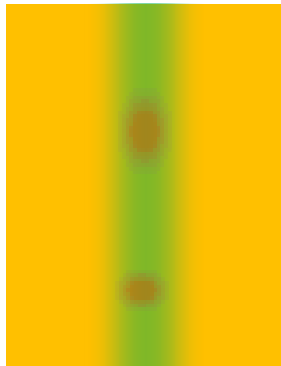
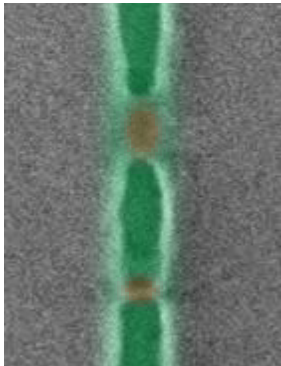


The results are suggesting that the resist polymer needs to have lower hydrophobicity, higher Rmax for better NOK.

# Interpretation

~ Low Hydrophobicity, High  $R_{max}$  → Good NOK ~

Given some stochastic failure is locally occurring before development,



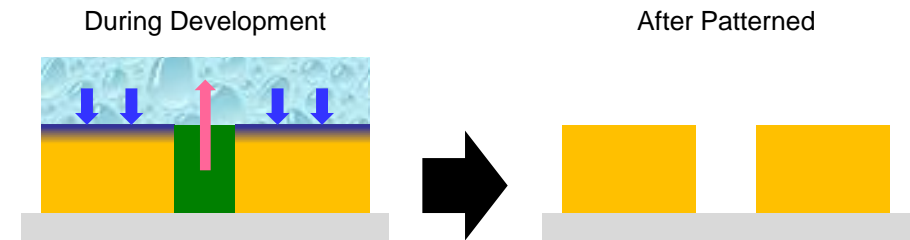
For example

- Optically ; photon displacement, absorption error
- Chemically ; acid creation/de-protection failure

Hydrophobicity,  $R_{max}$  of polymer would play for developer/rinse solvent,

## Better case

- Non-exposed area → Higher affinity
- Exposed area → More dissolvable



## Worse case

- Non-exposed area → Lower affinity
- Expose area → Less dissolvable



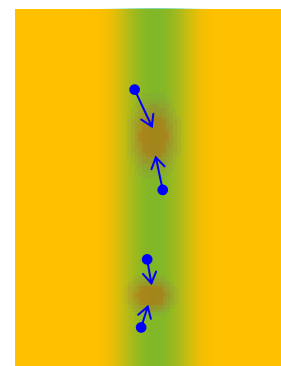
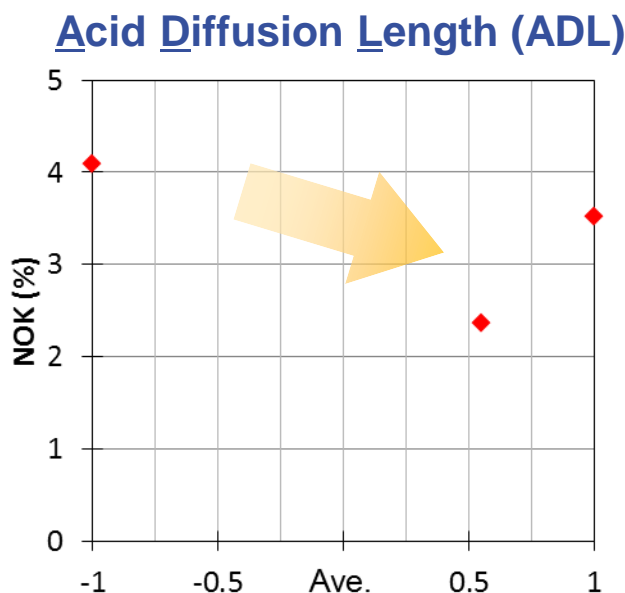
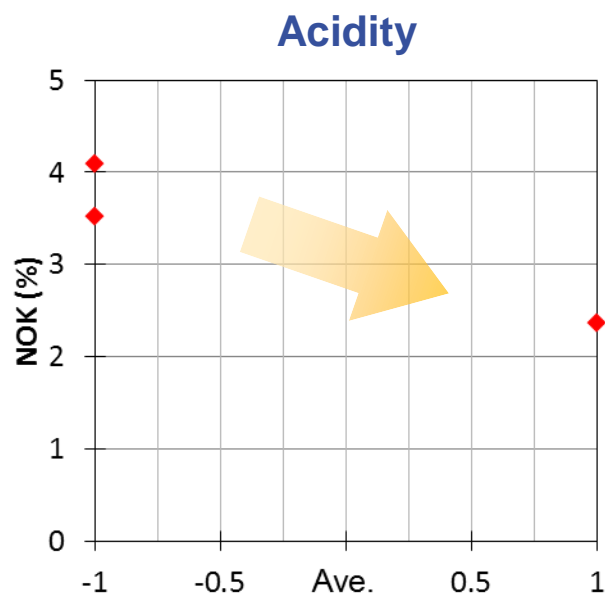
# PAG Parameters vs. NOK

\*Normalized range from average

Resist #	Polymer	PAG			Quencher
		name	Acidity*	ADL*	
Resist 01	Polymer-A	PAG-A	-1 (lowest)	-1 (lowest)	Q-A
Resist 02	Polymer-A	PAG-B	1 (highest)	0.55	Q-A
Resist 03	Polymer-A	PAG-C	-1 (lowest)	1 (highest)	Q-A

Polymer de-protection can be facilitated by,

- ✓ Stronger acid
- ✓ More diffusive acid



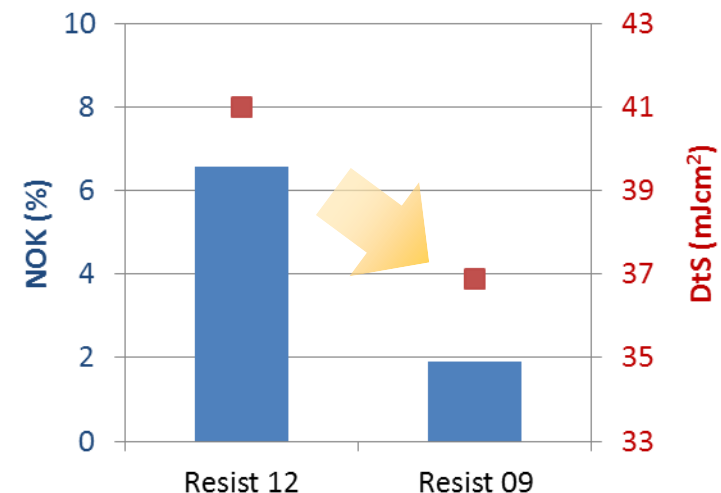
● = acid

**Slight trend on PAG acidity and ADL might (or not) exist. More data points are needed to justify.**

# Intermediate Conclusion

**Stochastic printability failures (=NOK % in this study) becomes better if the resist has following parameter,**

- **In polymer,**
  - Lower hydrophobicity
  - Higher Rmax
- **In PAG (possibly),**
  - Higher acidity
  - Longer acid diffusion length

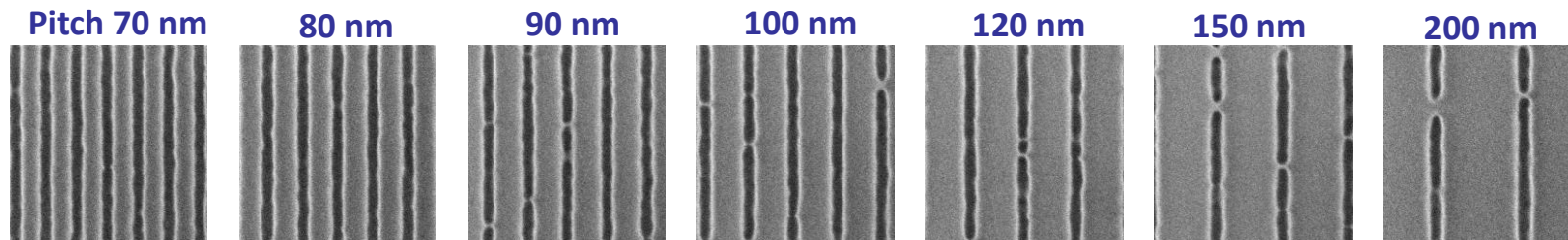


**In practical case of resist 09 vs. 12, we found the better NOK with improving resist sensitivity.**

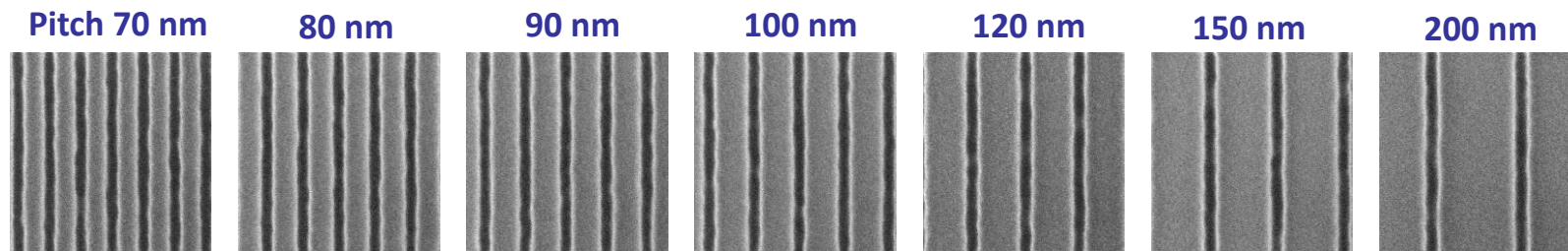
Resist #	Polymer				PAG			Quencher
	name	Hydrophobicity	Rmin	Rmax	name	Acidity	ADL	
Resist 12	Polymer-H	Higher	Lower	Lower	PAG-A	Lower	Lower	Q-A
Resist 09	Polymer-G	Lower	Higher	Higher	PAG-B	Higher	Higher	Q-A

# SEM Images in 1D structures

## Resist 12, DtS 40.0 mJ/cm<sup>2</sup>



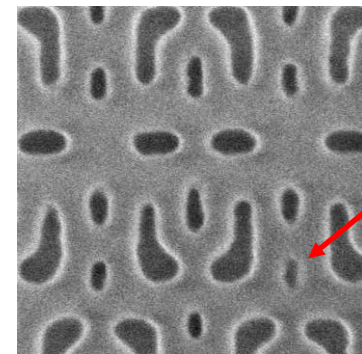
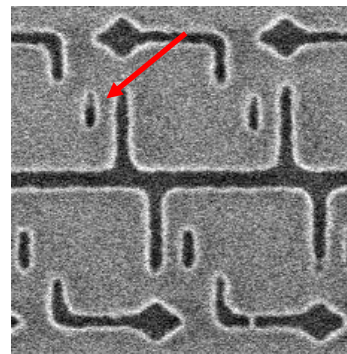
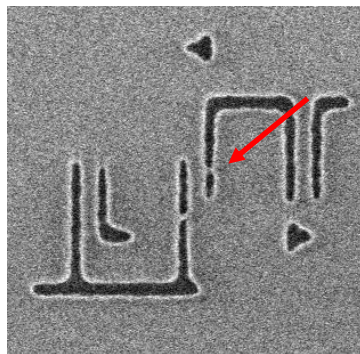
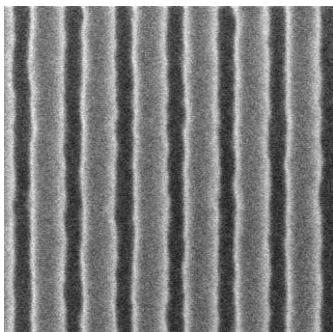
## Resist 09, DtS 36.9 mJ/cm<sup>2</sup>



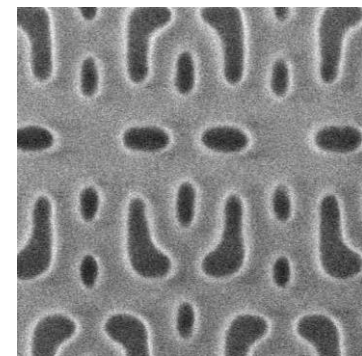
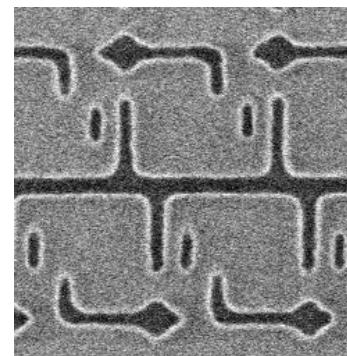
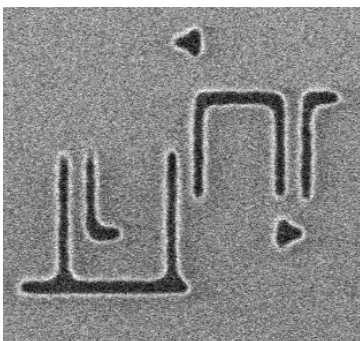
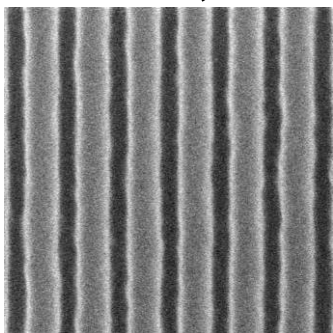
**Resist 09 showed better 1D trench printability than Resist 12 with higher sensitivity.**

# SEM Images in 2D structures

**Resist 12, DtS 40.0 mJ/cm<sup>2</sup>**



**Resist 09, DtS 36.8 mJ/cm<sup>2</sup>**

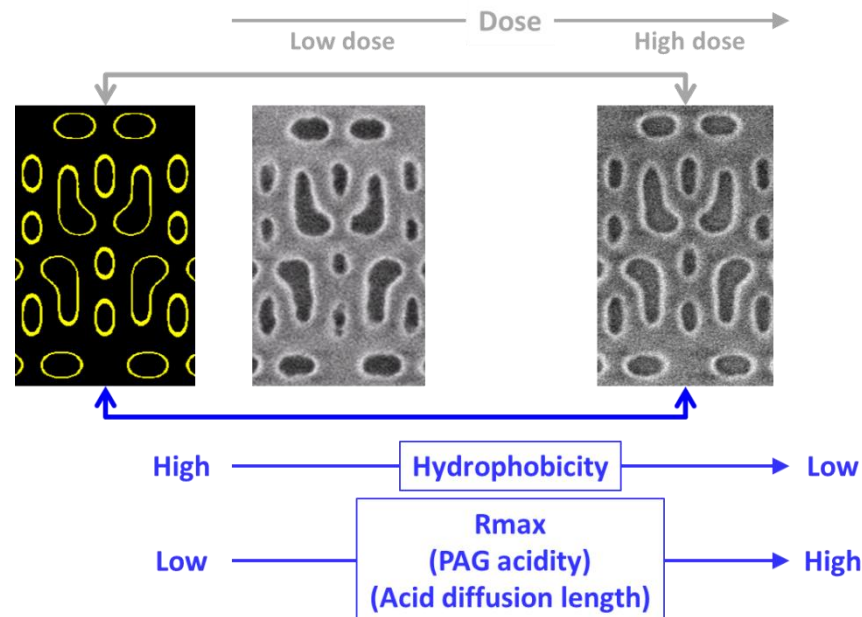


21 nm ~Dense trenches: both OK

**Resist 09 showed better 2D trench & hole printability than Resist 12 with higher sensitivity.**

# Summary

- Stochastic printability failures are one of the concerns for the processing on EUV.
- A dose increase can mitigate this problem, but it of course causes a throughput reduction.
- Our current research shows that also a proper choice of resist parameters helps reduce these printing failures



# Acknowledgement

- **Alessandro Vaglio Pret, John Biafore, Mark Smith (KLA-T)**
- **Daisuke Fuchimoto, Kei Sakai (Hitachi HT)**
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- **ASML/EXTREMETEC team at imec, for support of NXE3100 exposure**



**ASPIRE  
INVENT  
ACHIEVE**

*Materials Innovation*



With chemistry, we can.

